Chapter 2

Has Megaproject Management Lost Its Way? Lessons from History

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Abstract

Why do megaprojects frequently encounter performance problems, crisis and even failure, and how can this be averted? From the Eurotunnel linking Britain and France to expansion of the Panama Canal, huge projects often run off course or encounter nagging roadblocks. In this article, we illustrate three core management shortcomings that have significantly contributed to performance problems in megaprojects: the management of uncertainty, of stakeholders, and of contractors. We then draw on history – the Manhattan Project to develop the atomic bomb during World War II, and Cold War-era space and defense projects like Polaris and Apollo – to show that knowledge of how to overcome these issues has long existed, and could be used effectively in some megaprojects today. For example, Manhattan Project manager General Groves realized that big unforeseeable uncertainties in designing atomic weapons required discrete project management skills including flexibility, but these techniques have since been pushed aside in a managerial push for control that became the phased-planning or "stage-gate" process philosophy. And while some 1940s and 1950s successes may not be repeated today with the same managerial methods, because stakeholder complexity was lower at a time when huge projects served "national priorities," we argue that some mid-20th Century managerial techniques such as maintaining a common direction would help improve modern megaprojects.

The performance track record of megaprojects is dismal, even though the basic ingredients of successful large project management are not new. Put simply, the trick is to combine *uncertainty* in dealing with the difficulties of long time horizons and non-standard technologies with *stakeholder complexity* as expressed through the involvement of multiple powerful interested parties. (Flyvbjerg and Cowi 2004). This challenge was conquered in the successful creation of the atomic bomb in the 1940s; but 70 years on, some of the lessons of the Manhattan Project are not being heeded, and modern megaprojects are the poorer because of it.

Take the nuclear reactor industry, a poster child for delays and budget overruns. The current generation II EPR reactors were announced as the future in 2003, and construction began on the first project in Finland in 2005 with plans to launch operation in 2009. But this project will (as of the status in August 2015) not start operating before 2018 and has already incurred a cost escalation from €3.3B to €8.5B (World Nuclear Association 2015). Another project using the EPR technology in Flamanville in France is now expected to take more than double the original time frame and cost €9B rather than the initial estimate of €3.3B. (Le Monde, April 21, 2015). The Hinkley Point C project in the UK is too early in its construction to show large overruns, but to reflect high risks there are hefty price guarantees built into its building contract. (Taylor 2016, Chapter 12).

Nuclear power is not alone: Studies show that 90% of major projects are over budget, with overruns of above 50% being common (Flyvbjerg 2011). A country-specific study in Germany found that among 170 megaprojects, the average budget overrun was 73% (Kostka 2015). One study calls big cost overruns the "iron law of megaprojects." (Flybjerg 2014)

So this chapter illustrates that it is possible to identify a few core management shortcomings that have significantly contributed to such systemic-like failures. We then show that knowledge of how to address these shortcomings existed and was partly applied as early as during the Second World War. Third, we will use this review of past knowledge in order to sketch some recommendations for managerial measures that might help improve performance of megaproject management today.

1. Three Common Causes of Megaproject Failures

When we describe the spectacular failures of large projects over the last decades, three overarching themes arise.

1.1. Underestimation of, or Refusal to Acknowledge, Uncertainty.

Megaprojects are often started on the assumption that with enough planning, the design and project plan can be firmly designed at the beginning. But over long time frames, with non-standard technology and multiple interested parties, it is impossible to plan for everything – and parties then slip into a damaging fight for control that results in multiple redesigns and additional costs.

A case in point is the Circored project, a pioneering iron ore reduction facility to produce pure iron briquettes undertaken in Trinidad (Loch and Terwiesch 2002). The project started in 1995 with a target start of production in 1999, owned and run by the iron ore company Cleveland Cliffs using a new technology that Lurgi AG had developed and tested in a small prototype. An intensive risk analysis suggested that all problems could be anticipated and managed, but many unforeseen problems occurred in the scale-up, delaying the project by two years. Though the project ultimately succeeded technically, the delay made the facility vulnerable to the commodity price meltdown of 2002 and thus unprofitable. Ultimately, Cleveland Cliffs wrote the plant off and sold it at a steep discount to Mittal.

A key reason for the failure is that while Lurgi understood its technology's immaturity and technical risks, the plant owner rejected a longer testing phase on grounds that risks could be contained through proper planning and analysis. So ensuing problems had to be dealt with reactively, costing more in time and money than if properly addressed to begin with.

1.2. Stakeholder Neglect or Mismanagement.

Megaprojects normally require coalitions of active partners in addition to the support or at least passive tolerance of external stakeholders who don't participate directly. Peril inevitably results when stakeholders are ignored, or when a false agreement is finessed, causing conflicts to fester hidden behind wooly political statements.

A famous example is the Eurotunnel project, which dug a 50-km twin-tunnel under the English Channel between 1987 and 1994, through which passenger and freight trains now pass between Calais and Dover. The initial project had a seven-year duration and a (1987) budget of £4.8B, but ran over by 29% in schedule (after the original opening target of June 1993, freight operations started in May 1994 but full operations were not achieved until December 1994), and ran over budget by 65% for a total cost of £8B. Also, some initial specifications were not achieved, with trains running through the tunnel at 80km/h compared to the original target of 160km/h – thus extending travel time and reducing tunnel capacity. But most importantly, the operator, Eurotunnel plc, came out of the project so debt burdened that it could not turn a profit, and shareholders lost their investment twice (Garg et al. 2008), until finally the banks forgave a significant percentage of the debt in 2013.

The Eurotunnel troubles were *not* rooted in uncertainty: although some new tunneling machinery was used, related problems were quickly handled, and initial projections of revenues and operating profits turned out to be fairly close.

Instead, the root cause for Eurotunnel's woes was in the fraught relationships among the stakeholders: the construction consortium and the later operator Eurotunnel were in constant conflict and embroiled in lawsuits; the banks managed to transfer all risks, including inflation, to Eurotunnel, which resulted in a three-month work holdup and an inflated debt burden.

Stakeholder conflicts are a major source of project problems and are especially dangerous for megaprojects, which by their very nature involve many parties with the power to exert influence. Whenever a party is ignored, or when an agreement forces one party into agreement or superficially glosses over differences in views or interests, then these agreements likely break apart when changes disrupt the equilibrium – at which point the parties then no longer collaborate but work against one another (Loch et al. 2015).

1.3. Inflexible Contractor Management (Prominently, Awarding Work to the Lowest Bidder).

Many parties have to collaborate in order to accomplish megaprojects owing to their sheer size and variety of expertise required. The well-known practice of "bid low and sue later" is caused by project owners awarding contracts on the basis of the lowest bid price, forcing contractors to bid aggressively and then work inflexibly – asking for more compensation with every change in the project.

This was observed already 30 years ago (McDonald and Evans 1998), and is still alive and well – and criticized by a German government commission that examined practices in large public works projects (Kammholz 2015). A globally visible specific example is in the $5.25B megaproject for the expansion of the Panama Canal, which invited bids in 2009 and was scheduled to open in 2014. A Spanish-led consortium of construction firms won the $3.2B bid for the locks of the 50-mile waterway, underbidding a US-led rival consortium by $1B. But in 2014 the consortium demanded a $1.6B compensation from the Panama Canal Authority (PCA), the project owner, citing "breaches of contract" (for example, claiming they were misled about geological ground conditions). The dispute has already delayed the project to mid 2015. However, concerns were voiced right at the outset that the bid was too low, and that a cost increase would be required at some point (Kriel and Dowsett 2014). Although the PCA defends the original bid as reasonable, experts openly discuss the aggressive underbidding strategy used (Economist 2014).

1.4. Interactions Among the Themes

These three root causes of problems are even more difficult to address because they strongly interact. For example, stakeholders in the Eurotunnel project had differing interests such as the short-term view of the constructor versus the long-term operator's view. In an atmosphere of mutual distrust, even moderate uncertainties are difficult to address, leading to disputes (such as over cost overruns) and even further distrust. As a result, collaboration becomes even harder.

Yet although these challenges are difficult to address, there are potential solutions that have been ignored. Relevant knowledge has been available for seven decades, but much of this knowledge has been disregarded and not used effectively in the project community – as we describe next.

2. What Project Management Already Knew in the 1940s

The irony is that, historically, there were projects where these three problems were in fact overcome. This is particularly true of World War II and large postwar US military and space projects which, interestingly, are the roots of contemporary project management. Indeed, the Manhattan, Atlas, Polaris and Apollo projects, to name the most famous ones, were managed very successfully, and on schedule. It is therefore interesting to draw lessons from these cases. At the conceptual level, these projects did two crucial things right.

First, on the organizational level, they created almost from scratch a dedicated organization to overcome the traditional bureaucratic fights that plagued major R&D projects. The development of Intercontinental Ballistic Missiles (ICBM) within the US Air Force and the Navy is typical of this strategy. Consider briefly the Polaris case (Sapolsky 2003). The problem was to coordinate and integrate the functionally defined branches or bureaus and the dozens of firms involved. Moreover, as a new technology, ballistic missiles did not fit easily into the existing weapons acquisition structures: it was neither a bomber, nor a bomb, nor a guided missile. To overcome this problem, the Navy created the Special Project Office (SPO), a new body that had complete autonomy and power to manage the Polaris project. It was supervised by a brilliant and powerful project manager, Admiral William F. Raborn, who infused a sense of dedication and urgency into the entire team. He said: “Our religion was to build Polaris.” (Spinardi, 1994, p. 35) The creation of this structure constitutes unquestionably one of the key success factors of the Polaris project (Sapolsky 1972). And we find a similar logic, a dedicated organization led by a brilliant project manager, in all the aforementioned projects (the Manhattan Engineer District and L. Groves, the Western Development Division of the USAF and B. Schriever, The Office of Manned Space Flight and S. Phillips). Therefore, the success of these projects rested on “doing what it took” with almost unlimited project management power, supported by almost complete autonomy to take the right actions in the interest of achieving the goals.

Second, concerning the management of uncertainty, these PMs developed brilliant insights. They understood, right from the outset, that one does not know what one does not know. This cannot be more clearly stated than by General Groves when he stated that, given the huge unforeseeable uncertainties of the design of the atomic bomb, they were “proceeding in the dark” (Groves 1962, p. 40) and, therefore “had to abandon completely all normal orderly procedures” (ibid, p. 72).

What is fascinating is that they drew the right managerial conclusions: they combined experimentation (e.g., in the form of pilots), parallel pursuit of alternatives, and dedicated (possibly costly) actions to gather information as part of the core project activities. The Manhattan Project forcefully demonstrates the relevance of this approach: acknowledging that it was impossible to define, at the outset, the right design of an atomic bomb, Groves and the steering committee decided to simultaneously explore different technical solutions both for the production of fissionable materials and for the design of the bomb. This explains why the two bombs dropped on Japan had completely different designs and also how they succeeded in such a short time to overcome the tremendous scientific and engineering challenges. (Lenfle 2011) This strategy was directly transferred to the ICBM Atlas project (and others) through discussions between Groves, Oppenheimer and B. Schriever, chief of the Western Development Division of the USAF (Hughes 1998).

It is sobering for project management how these lessons have been lost in the course of the institutionalization of the discipline. Indeed, the principles of uncertainty management were theoretically well understood in the 1950s, especially the need for experimentation and adjustment, and the advantage of starting multiple parallel trials on subprojects in order to assure one successful outcome (Alchian and Kessel 1954, Arrow 1955, Klein & Meckling 1958). However, these principles had completely disappeared from PM textbooks and have only recently been rediscovered (from the view of multiple disciplines, e.g., Leonard-Barton 1995, Loch et al. 2006). Lenfle and Loch (2010) show how flexible approaches to uncertainty were abandoned in favor of a more control-oriented view of PM as the accomplishment of a clearly defined goal through a phased / stage-gate logic.

This process unfolded in three dimensions (Lenfle and Loch 2010):

1. On the political side, the deployment of ballistic missiles completely changed the context. The fear of a "missile gap" disappeared and the sense of utmost urgency of the military megaprojects faded away. This led to an important reorganization within the DoD in the form of the *Defense Reorganization Act* of 1958, which greatly increased the power of the Secretary of Defense over the armed services. It gave him the authority to "transfer, reassign, abolish or consolidate" service functions, and control over the budget. This paved the way for the "McNamara revolution." Coming from the Ford Motor Company, Robert McNamara, named Secretary of Defense in 1961, started a complete reorganization of the planning process in the DoD. His objective was to consolidate planning and budgeting, which hitherto had been two separate processes. He pursued his objective with the implementation of the famous Program Planning and Budgeting System (PPBS). This process was antipodean with the logic of the early missile projects and prompted a complete reversal in project management. Indeed, it emphasized the complete definition of the system *before* its development in order to limit uncertainty and institutionalize a phased approach. This *de facto* eliminated parallel trials and concurrency. Therefore, the phased-planning approach (now called Stage-Gate) became the project management model of the DoD and the newly formed NASA. This was enforced by the diffusion of managerial tools like PERT. In particular, a *NASA/DoD PERT/Cost Guide* was issued in 1962 and became part of the bidding process of both administrations, transforming these tools into *de facto* standards for project management. This limited the scope of project management for the ensuing decades. From now on, strategy was centralized at the DoD and Project Management's role was to execute given missions.

2. This shift had a theoretical counterpart. Indeed, the McNamara revolution was theoretically grounded in RAND thinking and its faith in rational decision making.[1] This view was clearly expressed by Charles Hitch, an eminent RAND member who later became comptroller of the Department of Defense under McNamara. In 1960, he published *The Economics of Defense in the Nuclear Age,* which introduced a broad audience to a view of defense as an economic problem of resource allocation to achieve a desired objective. This view had major consequences for project management: the focus gradually changed from the "performance at all costs" attitude of the first missiles projects to one of optimizing the cost/performance ratio. This new logic is clearly visible in the early literature on project management. For example, *Systems Analysis and Project Management* (1968) by Cleland and King became a classic. The book is typical of the phased logic. It consists of two parts that corresponded to the two key project phases. The first advocated the power of systems analysis to analyze complex strategic issues and define project missions. The second part dealt with project execution and emphasized the need to create a specific project organization to integrate stakeholder contributions, along with project planning and control using formal methods. The result of all of these events was that by the early 1970s, the phased approach had become "natural."

3. The last stage of this standardization process was the creation, in 1969, of a professional organization: the US Project Management Institute. Indeed, the years following the success of Polaris saw a plethora of publications and an intense promotion of the PERT/CPM method by numerous consulting firms (Vaszonyi 1970). The planning method was viewed as synonymous with success in the management of large projects. The idea of a professional association arose in this context within the tight-knit community of PERT and CPM users (R. Archibald, E. Benett, J. Snyder, N. Engman, J. Gordon Davis and S. Gallagher). Since all its founders were project control experts, it was natural for the PMI to focus on control tools, such as PERT/ CPM. Therefore, for the next two decades, "modern project management" became equated with PERT/CPM after Polaris and the MacNamara revolution (Snyder 1987).

This, as the reader will recognize, provides the basic principles of the dominant model of project management today, the stage-gate process. The problem is that this rational view of project management oversimplifies the processes at stake, particularly for innovative projects and for megaprojects with their inbuilt unforeseeability (because of long time frames and stakeholder complexity). Moreover, this leads, as argued by Lenfle and Loch, to misinterpretations of the success factors of these projects. For example, Apollo is remembered in the project literature for the setting up of a complex project management system organized around a phased approach (Seamans 2005, Johnson 2002). While this unquestionably contributed to getting back on track during the project crisis of 1962-63, this narrow view neglects the upstream exploratory work and the fact

[1] McNamara's thinking was rooted in and had a major impact on "cold war rationality," i.e. the belief that one could find the optimal solution beforehand. Here, the reader may refer to Erickson et al. (2013).

that the phased approach was implemented quite late in the project. However, the fact is that this control-oriented approach of project management remains dominant today.

3. The Limitations of the Breakthrough Project Management Styles of the 1950s

Based on the previous discussion, we might ask the question whether the issue is to "get some of the capability of the 1940s and 1950s back." But this, we think, would be too simple. Indeed, these projects unfolded in a very specific context and, therefore, were not exposed to the full spectrum of complications that face the megaprojects of today. One has to remember that, for all these projects, the context was the highest level of national urgency either because of World War II (Manhattan) or the Cold War with the USSR (Atlas, Polaris and Apollo). This had two major consequences.

First, the project goals reflected the military nature of the missions and were, in a sense, "simple" (although technically impressive): build a nuclear bomb, build a missile that can hit a small target from a long distance, start the missile from a submarine, or go to the moon[2]. These do not reflect the goal complexity of projects that, today, inevitably have a societal component.

Second, the Cold War and the competition with the Soviets led to the suppression of any debate around the projects. It is useful here to remember John F. Kennedy's address to the Congress that formally launched the Moon project:

> "*If we are to win the battle that is going on around the world between freedom and tyranny, if we are to win the battle for men's minds, the dramatic achievements in space which occurred in recent weeks should have made clear to us all, as did the Sputnik in 1957, the impact of this adventure on the minds of men everywhere who are attempting to make a determination of which road they should take. (…) We go into space because whatever mankind must undertake, free men must fully share. (…) I believe this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish*." John F. Kennedy, Special Message to the Congress on Urgent National Needs, May 25, 1961.

Indeed, if the stakes were "the battle between freedom and tyranny," there could be no debates around the project[3]. In other words, if we rely on contemporary concepts, stakeholder disagreements were absent or small. There were no parties that stopped support, or protesters that blocked further work, because they no longer agreed with changed outcomes, or external groups that demanded transparency and accountability.

[2] Apollo is an ambiguous case since it is a civil project largely managed by the military after 1963.

[3] On the Manhattan Project, there was no debate simply because it was a "black", completely secret, project. Even Harry Truman, Roosevelt's vice-president, ignored the existence of the project until he became president in April 1945.

This was also true for supplier management. These project teams had huge power over their suppliers – again, these were military projects where suppliers were paid well but had to unquestioningly carry out orders. In fact, the entire organization was designed to avoid politics. As demonstrated by Hughes (1998) for Atlas and Sapolsky (1972) for Polaris, the main goal of the creation of the WDD and the SPO was explicitly to avoid the bureaucratic fights and politicking that, traditionally, plagued large R&D projects. They were, in a sense, "closed" projects (Edwards 1996, Hughes 1998). Politics was reduced to the army and the government. There could be debates, but no protest outside likely to stop the project (Beard 1976). It was possible for Admiral Raborn to "build a fence to keep the rest of the Navy off of us" (Sapolsky, p. 124) and to "engineer the politics of the program so as to provide resources without interference" (Spinardi, p. 35-36). Therefore, the question of stakeholder management was literally out of the scope.

This very specific context disappeared with the end of the Cold War and the emergence of a networked world – it is no longer the case in megaprojects today. Now the challenge is to manage megaprojects in an "open" context in which no project team can hope to keep the outside world behind a fence. In this perspective, T. Hughes (1998) brilliantly demonstrates that the "system engineering" methods developed for military projects failed when confronted with civil megaprojects like the famous Boston Central Artery Tunnel. Here, the challenge was to deal with the messy complexity of multiple stakeholders, each with different objectives and constraints. F. Salvucci, the Boston CA/T key figure, had to patiently negotiate his way through the maze of the Boston area, discussing with engineers, community groups, the City, the State of Massachussets, etc., around to-be-defined criteria, such as the design of a bridge. Therefore, as argued by Lundin et al. (2015), "The traditional view of the 'project client' as the single focal interlocutor of the project vanishes, giving place to a complex fuzzy system of diversified actors that has to be 'managed' in novel sophisticated governance and communication processes" (p. 201-202). The problem is all the more important because, they argue, there is an ever-growing demand of accountability for public and private megaprojects. General Groves never had to deal with this situation.

In other words, we can't simply go back to the heyday of 1950s project management – what worked brilliantly then would be insufficient today. And yet, it is still worthwhile to repeat the lessons on uncertainty management from the 1950s, as some of the recent failed megaprojects simply violated what is known about uncertainty management. Moreover, knowledge on all three key drivers of megaproject failure has slowly accumulated over the last 50 years, not only on uncertainty management but also on stakeholder and contractor management. We will review the ley lessons of this knowledge history in the last section.

4. Lessons and Recommendations

4.1. Managing Uncertainty

Building on the work from the 1940s described earlier, project management theory has, since the stage-gate process became dominant, been able to articulate that many projects are characterized by variation (many small influences causing a possible range of duration and costs on a particular activity), which can be addressed by buffers, and foreseeable uncertainty or risk (identifiable and understood influences that the project team cannot be sure will occur, so different outcomes are possible), which can be addressed by planned and "programmed" risk management that "triggers" contingent actions depending on which risks occur (De Meyer et al. 2002). However, megaprojects suffer also from unforeseen uncertainty, which can't be identified during project planning. The team either is unaware of the event's possibility or cannot create the contingencies. Unforeseeable uncertainty may be caused by large "unthinkable" events, or by many influences (including stakeholder actions) that interact through complexity. Unforeseeable uncertainty requires more flexible and "emergent" approaches than smaller uncertainty levels do (and than the stage-gate process has allowed for).

Still, the presence of unforeseeable uncertainty can be diagnosed. For example, discovery-driven planning (McGrath and MacMillan 1995, 2000) proposes to explicitly acknowledge that unknown unknowns exist and to uncover them with analyses such as assumptions checklists. Similarly, Loch et al. (2008) illustrated with the example of a start-up venture project how the presence of unknown influences can be diagnosed by systematically probing for knowledge gaps in the project, building intuition about areas where unknown events may be looming. Two fundamental approaches exist for this level of unforeseeable uncertainty: trial-and-error learning and selectionism (Leonard-Barton 1995, Pich et al. 2002, Loch et al. 2006).

Under *trial-and-error learning*, the team starts moving towards one outcome (the best it can identify), but is prepared to repeatedly and fundamentally change both the outcome and the course of action as new information becomes available. Exploratory experiments, aimed at gaining information without necessarily contributing "progress", are an important part of this approach; failure of such experiments is a source of learning rather than a mistake. It is therefore important to track the learning and reduction in knowledge gaps rather than tracking only the progress towards a target. Well-known examples are pharmaceutical development projects, in which promising indications often emerge during large scale trials via unexpected (positive) side effects.

Alternatively, the team might choose to "hedge" and opt for *selectionism*, or pursuing multiple approaches in parallel, observing what works and what doesn't (without necessarily having a full explanation why) and choosing the best approach ex post facto. Examples of this approach abound, including Microsoft's pursuit of several operating systems during the 1980s (Beinhocker 1999), or "product churning" by the Japanese consumer electronics companies in the early 1990s (Stalk and Webber 1993).

In a large-scale empirical study of 65 new venture projects, Sommer et al (2009) showed that the best combination of learning and selectionism, as measured by their effect on project success, depends on the level of unforeseeable uncertainty in the project and the complexity of the project (Figure 1). When both uncertainty and complexity are low (lower left quadrant), planning and standard risk management are up to the task and the most efficient. When unforeseeable uncertainty looms large, be flexible and apply trial and error. When complexity is high, use parallel trials and narrow the field down to the best as soon as possible. The hardest situation is in the upper right quadrant, which is where megaprojects usually find themselves and where unforeseeable uncertainty and project complexity combine. It turned out that the highest success level was associated with parallel trials if they could be kept alive until uncertainty had been reduced to the point that all important risks were known. Otherwise, trial and error performed better. Of course, in any large project, trial and error and selectionism can be combined and applied differently across sub-projects.

Unforeseeable Uncertainty	Complexity: Low	Complexity: High
High	**Learning** Flexibility to fundamentally re-define business plan and venture model	**Selectionism** Selectionism is most effective *if* choice of best trial can be deferred until unk unks have emerged (true market response is known)
Low	**Planning** • Execute plan toward target • risk identification and risk management • Learning and updating	**Selectionism** • Plan as much as possible • Try out several alternative solutions and choose the best as soon as possible

Figure 1: When to choose trial-and-error-learning or selectionism (from Sommer et al. 2009)

The largest challenge lies in the managerial structures and control-mindedness in large corporations, partially prompted by the stage-gate process revolution of the 1960s that we have discussed earlier. It makes it very difficult for managers in large organizations to take on risks. For example, one study on “breakthrough innovation” in large companies shows that they use a stage-gate-like approach to selecting and executing large innovations, which pushes managers to conservativism and early termination of risky projects (He 2015). Similarly, Sehti and Iqbal (2008) demonstrated that the Stage-Gate Process leads to project inflexibility, which, for innovative projects, is synonymous with failure. Even more fundamentally, the stage-gate process has shaped an “aesthetic” of eliminating uncertainty and experimentation through rigid upfront planning and control. For example, a study of relationships between startups and investors found that investors reacted with “punishment” (i.e., by enforcing business reviews) to evidence of parallel trials and (to a lesser degree) trial and error iterations (Loch et al. 2011). Managers are, in principle, fully capable of intelligently responding to unforeseeable uncertainty, as R&D management and many experienced project management organizations amply demonstrate. However, much education is needed in order to equip management in many (particularly public) organizations, investors, and critically the public, of the flexibility required to deal with uncertainty.

4.2. Stakeholder Management and Project Governance

No universally agreed "national agenda" exists any longer, based on which the brilliant projects in the 1950s could successfully proceed, because megaprojects touch on too many interests and agendas to still be able to be pushed by any central will. Consultation and involvement of powerful interested parties has become a must. On the other hand, political compromises do not make good bases for decisions, and muddled goals and inconsistent decisions based on fluctuating agreements destroy projects. How can these two imperatives be reconciled? This is a question of project governance.

Project teams execute, but the scope and strategic positioning of a project is set at the level of project governance, typically at the level of the "steering committee" (SC). Loch et al. (2015) examined effective and non-effective SC practices in 17 complex and uncertain projects (innovation as well as organizational change), and found that the SC is the place where representation of interests (including consultation) needs to be combined with the production of a shared project vision and the translation of this vision into operational plans – in order to effectively identify conflicts and solutions as the environment of the project changes.

Several specific principles arise from the study:

- Stakeholder representation: the SC needs to represent the most important and powerful parties that have an interest in the megaproject (such as government, suppliers, or customers). At the same time, the size of the SC must not grow too large (by allowing "anyone with interest to participate") because large groups become too difficult to manage and keep together.
- Goal agreement: The SC has the critical responsibility to articulate a project vision that is at least acceptable to all parties, and then translate it into operational goals and targets that expose key conflicts. "Motherhood and apple pie" goals regularly get thrown out during later operational phases when conflicts inevitably do occur. Only if the conflicts are negotiated at the outset (in a way that maintains a shared project vision) can the goals evolve and change in negotiated ways that allow maintaining a shared vision.
- Staying informed and renegotiating during crises. The SC must invest enough time and effort to understand the key issues of the project (insisting on translation of technical language and issues into the strategic policy or business language that is needed to maintain the strategic positioning of the project). The SC must also invest the time and effort to stay informed, so when changes and crises occur (both inevitable over the time horizon of megaprojects), project modifications can be renegotiated in ways so the parties maintain their agreement/support. If a party feels excluded or taken advantage of, projects fail, but if the SC can successfully manage one crisis together, it becomes stronger in managing the next.

– Keeping the project team aligned. The SC must maintain a position of control, which means in this context understanding the key issues rather than maintaining and enforcing ("come what may") an initial project plan. Trust needs to be built with the project team that bad news and changes are treated reasonably, demanding solutions and accountability, but not looking for scapegoats to punish – otherwise, information about the true status of the project will not be forthcoming. This is necessary because changes *will* happen in a megaproject, and the SC needs to set up itself as well as its project team to be able to address these changes in ways that do not lead to the typical symptoms of megaproject disasters – such as mission creep, late mission changes because of political maneuvering, accumulated unaddressed problems, or the falling out with an important stakeholder.

Several key challenges exist that make these principles difficult to achieve: Interest conflicts and differences in thinking styles among stakeholders make the achievement of true alignment a long affair (leading to longer planning times) and consume significant managerial effort during a project. The temptations are ever present to not invest enough effort, or to exploit political circumstances of unbalanced power to one's own advantage.

This is also where the widely observed temptation of "low-balling early [on costs] and then present a fait-accompli to the stakeholders" (Flybjerg 2007) comes in. While this is certainly true in some cases, it is not inevitable. Evidence in Loch et al. (2015) suggests that if the SC represents stakeholders and seeks the dialogue with them, and if it is sufficiently involved with the project team to be able to follow and evaluate progress, success overestimation can be avoided. Of course, this leaves out situations where a skeptical public (or political establishment) is simply not willing to accept a project under a realistic scenario, and the only way to get the project approved is "lying" about it. But whoever engages in misrepresentations in order to get the project started ("they will learn and change their minds later") is running severe risks both for their own careers, as the project later runs into difficulties pre-programmed by the unrealistic initial estimates, and for the public, whose faith in project execution capabilities becomes undermined. Yes, it may be true that (for example) the Eurotunnel was a significant macro-economic success in hindsight, connecting London and Paris in ways that were previously unthinkable. But on the way there, many shareholders lost their money and careers of good people involved were damaged, and so initial overpromising is perilous and not advisable even if one might be able to construct a long-term justification for it.

4.3. Contractor Management

Contracts are core vehicles of governing partners and the sub-contractors of pieces of work in projects, and they form a complex web of relationships in megaprojects. But contracts can handle only limited complexity (a contract can quickly run into thousands of pages, which means they become ineffective), and they are inflexible where flexibility is required to deal with the inevitable changes in megaprojects. "A contract is a dangerous instrument and should always be approached with trepidation and caution. … Theoretically, the aim of a written contract is to achieve certainty of obligation of each party, the avoidance of ambiguities, and such definiteness of understanding as to preclude ultimate controversy. In practice, construction contracts are generally formed not to definitely fix obligations, but to avoid obligations" (MacDonald and Evans 1998, 1-2). Specifically, contracts cause the temptation to explore gaps in the understanding of the counterparty to create obligations that one can then exploit – a fallacious expectation because the other side usually finds a way to sooner or later stall in their turn or to retaliate. (Von Branconi and Loch 2004) The well-known temptation to "bid low and sue later" falls in this context, but it often leads to protracted business and legal battles, victimizing the project.

Much evidence has been accumulated that contracts need to be designed with *flexibility*, and they need to be complemented with *relationships*. A good example is the celebrated Heathrow Terminal 5 project, which applied an integrated approach that incorporated careful strategic governance (accomplishing system integration), within diligent process management that included supplier selection by track record (rather than the lowest bid price) and flexible contracts that rewarded problem solving (Davies et al. 2009b). The project owner BAA "changed the rules of the game" by creating a new type of agreement based on two fundamental principles: the client bears the risk and works collaboratively with contractors in integrated project teams. BAA had to take responsibility for risks and uncertainties, whilst creating an environment within which suppliers could find solutions. Suppliers were repaid all the costs on a cost-transparent "open book" basis and incentivized to improve their performance and innovate by bonuses for exceeding previously agreed "target costs" and completion dates. If the performance of a project exceeds target costs, the profits are shared among team members. This contractual approach was underpinned by routines to expose and manage risks rather than transfer or bury them, and offered incentives for innovation and problem solving (Davies et al. 2009a, 24-25).

The Heathrow T5 project addressed one fundamental problem with contracts---they cannot specify all desired outcomes beforehand in the complex and uncertain environment of a megaproject, and fixing any outcomes (no matter with how many "contingencies) opens up incentive conflicts when contractors either cannot deliver or can deliver in unforeseen ways. The cost-reimbursement contracts with "innovation bonuses" offered a way out of this dilemma. But it is possible to go even further in turning contracts from fixed outcome descriptions into vehicles for collaborative problem solving. One example for this is the OSA Alliance between Orange (France Telecom's mobile telephone arm) with its partners in managing roaming, the complicated agreements that allow regional telecom operators to provide service for a customer from other regions and get reimbursed by the telecom operator who has a contract with the customer and charges this customer for the roaming (Van Der Heyden et al. 2006). The "contract" that partner operators in the alliance signed up for did not specify any specific collaboration procedures or outcomes, but was nothing but a specification of a *collaborative problem solving procedure*: how would the group make decisions in setting up a technical system, or a customer agreement, or a revenue sharing when it arose. Decisions were indeed made by voting, with safeguards that neither the large operators (with a revenue majority) nor the many small operators (with most votes) could force through agreements. Each specific agreement itself (what would normally be seen as a contract) became a mere technical description. This structure of agreements allowed the partners to keep collaborating flexibly and robustly in an environment of changing technologies and regulatory regimes (the regulatory bodies tightened rules on roaming which had become very profitable). However, when we discuss such collaboration structures with project and program managers, they usually are very uncomfortable because it feels to them like a "loss of control." This is another example of the control "aesthetics" that the dominance of the stage-gate process has created in project management.

And yet, there are again large challenges in adopting these new methods that would allow addressing the systematic problems that have plagued megaprojects. The temptation to use "market forces" to depress prices to contractors, using unbalanced power to get one's way (if only for a short period), is ever present. As a case in point, the Heathrow T5 owner BAA was acquired in 2006 and, "in a complete reversal of strategy (and to the surprise of many in the UK construction industry) decided to revert back to the traditional role of client as procurer rather than project manager, relying on "risk-shifting contracts", detailed up-front specifications and inflexible routines" (Davies et al. 2016).

Similarly, the authors have discussed the OSA "framework contract" approach with managers from many companies and have witnessed directly how deeply threatening managers find such an approach – it feels to them like they are giving away control over their own fate. Yet another cultural and "aesthetic" influence that has been connected to the stage-gate process, which adds a specific definition of "professional standards" to the earlier mentioned short-term temptations in making it very difficult to make the new methods in megaproject management enter the mainstream.

5. Conclusion

System engineering and technical complexity are well understood, but uncertainty and stakeholder complexity are still the big challenges for megaprojects. Avenues have been identified to address these challenges that require behavioral changes: these include resisting the temptation to press one's own advantage with contractors; accepting some loss of predictability and control; patience in bringing the multiple sides to the table that are always present in megaprojects, and the discipline to maintain a common direction that allows progress-directed decision making rather than merely conflict-avoiding compromises. Many of these techniques will require companies to learn new and potentially daunting behavior; but in fact many of these managerial mechanisms are tried and true techniques that worked wonders for megaprojects a few generations ago and could help point the way to a brighter future for huge projects in the future.

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